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CONTENTS

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Title

ANALYSIS OF OPTICAL SOLITON PROPAGATION IN BIREFRINGENT FIBERS

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INTRODUCTION:

Before the development of optical communication systems, two major forms of communication systems were employed. In the first of these, namely, electrical communication system, information is encoded as electrical pulses and transmitted through coaxial cable; the other system, i.e., microwave system, uses electromagnetic waves with frequencies in the range of 1 - 10*GHz* to transmit the signal .These two systems are limited either by bandwidth due to high frequency-dependent loss of coaxial cable of the electrical system, or bit rate due to the low carrier frequencies of the microwave system. Fortunately, these two obstacles could be overcome by using optical communication system, thanks to the invention of the laser in 1960 and the breakthrough technology of low-loss optical fibers in 1970. Specifically, the high frequencies (~100 *THz*) of the optical pulses increase enormously the bit-rate of the system and the fiber loss has been reduced to below 20 *dB/km* in a broad wavelength range around 1µm. While, for the advantage of low cost, electrical and microwave transmission technologies are still preferred for short distances and relatively low bandwidth applications, such as cable TV (Television), CCTV (Closed Circuit Television). Fiber-Optic technology is generally used in telecommunications for its inherently high data-carrying capacity and the exceptionally low loss of the optical fiber.

SOLITONS AN INTRODUCTION:

The evolution of optical communications revolutionized the speeds of data transmission in communication networks. The enormous bandwidth available at carrier frequencies of THz range increased rate of information greatly and backbone networks at 2.5 Gbps became a reality. The growing demand for faster information transfer and also the increased demand for information itself has necessitated that speeds beyond 2.5 Gbps be achieved.

We know that information as electrical signals are sent in the form of pulses and the amount of information that can be transmitted is limited by the pulse width , lesser the pulse width, higher the bit rate and greater the rate of information transmission. But as we transmit electrical pulses in fibers due to material dispersion the pulses spread and overlap. This results in loss of information. The spreading relative to the initial pulse width is more if the pulse has very small width than if it has larger width. So if we try to send more information by lessening the pulse width and hence increasing the bit rate, we would have to encounter dispersion and it maybe so harmful that large amounts of information loss can happen.

To prevent loss of information generally error control coding techniques are used but these only decrease the amount of actual information transferred in the sent bits in a given time. Another way is suitable line coding, so that information can be obtained despite dispersion. One more solution is Dispersion compensation i.e. to counter the spreading of the pulse by introducing a dispersion of the opposite kind that reduces the pulse widths so that the two effects nullify and there is no net change in the pulses transmitted. But then many other phenomena like non linearity in fiber, polarization mode dispersion etc become prominent. Is there a solution that overcomes all these problems?

Solitons have been proposed and implemented successfully as the solution to the problem of increasing the bit rate higher. Using solitons, bit rates as high as 40 Gbps have been achieved. So what are solitons? Why are they solutions to the problem of increasing bit rate? What are the limitations in implementing soliton based communication systems? How are they overcome? My project has been step towards answering these questions.

OVERVIEW OF THE PROJECT:

In this project we are going to deal with the effects of polarization-mode dispersion and third-order dispersion on soliton pulse propagation and also studied effective pulse dynamics in single mode fiber. In this report we are discussing about optical pulse propagation inside single mode fiber , polarization mode dispersion is discussed, effects of third-order dispersion and birefringence on solitons propagation and methods for solving coupled nonlinear Schrodinger equations is discussed, and finally the simulated results are presented

OPTICAL PULSE PROPAGATION INSIDESINGLE MODE FIBER:

We obtained the nonlinear Schrodinger (NLS) equation that governs propagation of optical pulses inside single-mode fibers. For pulse widths >5 ps, one can use equation given by

$$i\frac{\partial A}{\partial z}=-\frac{i\alpha}{2}A+\frac{\beta_2}{2}\frac{\partial^2 A}{\partial t^2}-\gamma|A|^2 A \qquad (5)$$

Where A is the slowly varying amplitude of the pulse envelope and T is measured in a frame of reference moving with the pulse at the group velocity V_g. The three terms on the right-hand side of Eq. (5) govern, respectively, the effects of fiber losses, dispersion, and nonlinearity on pulses propagating inside optical fibers. Depending on the initial width T_0 and the peak power P_0 of the incident pulse, either dispersive or nonlinear effects may dominate along the fiber. It is useful to introduce two length scales, known as the dispersion length L_D and the nonlinear length L_{NL}. Depending on the relative magnitudes of L_D, L_{NL} and the fiber length L pulses can evolve quite differently.

Let us introduce a time scale normalized to the input pulse width T_0 as

$$\tau=\frac{T}{T_0}=\frac{t-z/V_g}{T_0} \qquad (6)$$

At the same time we introduce a normalized amplitude U as

$$A\,(z,\tau)=\sqrt{P_0}\exp(-\alpha z/2)U(z,\tau) \qquad (7)$$

Where P_O is the peak power of the incident pulse. The exponential factor in Eq. (7) accounts for fiber losses. By using Eqs. (5)– (7), U (z, τ) is found to satisfy

$$i\frac{\partial U}{\partial z}=\frac{\mathrm{sgn}(\beta_2)}{2L_D}\frac{\partial^2 U}{\partial \tau^2}-\frac{\exp(-\alpha z)}{L_{NL}}|U|^2 U \qquad (8)$$

Where $\mathrm{sgn}(\beta_2)=\pm 1$ depending on the sign of the GVD parameter β_2 and $L_D=\frac{T_0{}^2}{\beta_2}$,

$$L_{NL}=\frac{1}{P_0\gamma} \qquad (9)$$

The dispersion length L_D and the nonlinear length L_{NL} provide the length scales over which dispersive or nonlinear effects become important for pulse evolution. Depending on the relative magnitudes of L, L_D and L_{NL}, the propagation behavior can be classified in the following four categories.

When fiber length L is such that $L \ll L_{NL}$ and $L \ll L_D$, neither dispersive nor nonlinear effects play a significant role during pulse propagation. This can be seen by noting that both terms on the right-hand side of Eq. (8) can be neglected in that case. i.e., the pulse maintains its shape during propagation. The fiber plays a passive role in this regime and acts as a mere transporter of optical pulses (except for reducing the pulse energy because of fiber losses). This regime is useful for optical communication systems. For $L \approx 50$ km, L_D and L_{NL} should be larger than 500 km for distortion-free transmission. One can estimate T_0 and P_0 from Eq. (8) for given values of the fiber parameters β_2 and γ. At $\lambda = 1.55\mu m$ $|\beta_2| = 20\ ps^2$/km, and $\gamma = 3\ W^{-1}km^{-1}$ for standard telecommunication fibers. The use of these values in Eq. (8) shows that the dispersive and nonlinear effects are negligible for $L < 50$ km if $T_0 > 100$ ps and $P_0 = 1$ mW. However, L_D and L_{NL} become smaller as pulses become shorter and more intense. For example, L_D and L_{NL} are $\approx$ 100 m for $T_0 \approx 1$ ps and $P_0 \approx 1$ W. For such optical pulses, both the dispersive and nonlinear effects need to be included if fiber length exceeds a few meters.

When the fiber length is such that $L \ll L_{NL}$ but $L \approx L_D$, the last term in Eq. (8) is negligible compared to other two. The pulse evolution is then governed by GVD, and the nonlinear effects play relatively minor role. The effect of GVD on propagation of optical pulses is discussed in this chapter. The dispersion-dominant regime is applicable whenever the fiber and pulse parameters are such that

$$\frac{L_D}{L_{NL}} = \frac{\gamma P_0 T_0^2}{|\beta_2|} \ll 1 \qquad (10)$$

When the fiber length L is such that $L \ll L_D$ but $L \approx L_{NL}$, the dispersion term in Eq. (5) is negligible compared to the nonlinear term. In that case, pulse evolution in the fiber is governed by SPM that leads to spectral broadening of the pulse. The nonlinearity-dominant regime is applicable whenever

$$\frac{L_D}{L_{NL}} = \frac{\gamma P_0 T_0^{\ 2}}{|\beta_2|} \quad >>1 \qquad (11)$$

This condition is readily satisfied for relatively wide pulses ($T_0 >$ 100 ps) with a peak power $P_0 \approx 1$ W. Note that SPM can lead to pulse shaping in the presence of weak GVD effects. If the pulse develops a sharp leading or trailing edge, the dispersion term may become important even when Eq. (11) is initially satisfied.

When the fiber length L is longer or comparable to both L_D and L_{NL}, dispersion and nonlinearity act together as the pulse propagates along the fiber. The interplay of the GVD and SPM effects can lead to a qualitatively different behavior compared with that expected from GVD or SPM alone. In the anomalous-dispersion regime ($\beta_2 < 0$), the fiber can support solitons. In the normal-dispersion regime ($\beta_2 > 0$), the GVD and SPM effects can be used for pulse compression. Eq. (5) is extremely helpful in understanding pulse evolution in optical fibers when both dispersive and nonlinear effects should be taken into account.

SPLIT-STEP FOURIER METHOD:

We split the computation of A over distance L_c into 4 steps:

Step 1. Nonlinear step: Compute $A_1 = \exp(L_c N) A(Z,T)$ (by finite differences);

Step 2. Forward FT: Perform the forward FFT on A_1: $A_2 = F \ A_1$;

Step 3. Linear step: Compute $A_3 = \exp(L_c L) \ A_2$;

Step 4. Backward FT: Perform the backward FFT on A_3: $A(Z + L_c, T) = F^{-1} \ A_3$;

After step 4 we will get the soliton pulse amplitude after traveling length L_c .hence to find the soliton amplitude after traveling long distance we have to repeat the above algorithm for many number of iterations.

SIMULATIONS AND RESULTS:

PULSE PROPAGATION IN NONLINEAR REGIME:

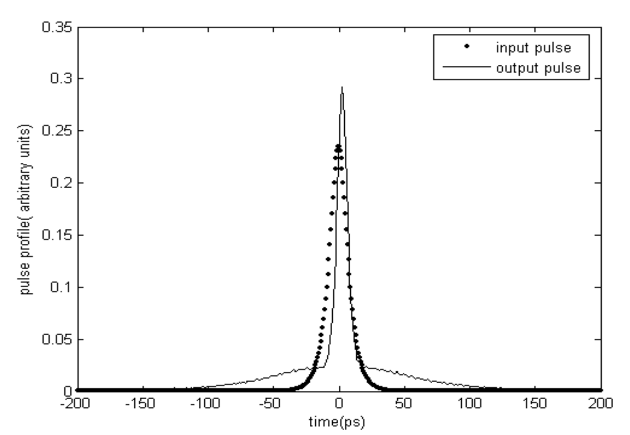


Fig.1 pulse profile in nonlinear regime with $n_2=9/2$, $\alpha_2=2/3$and $d_0=4$

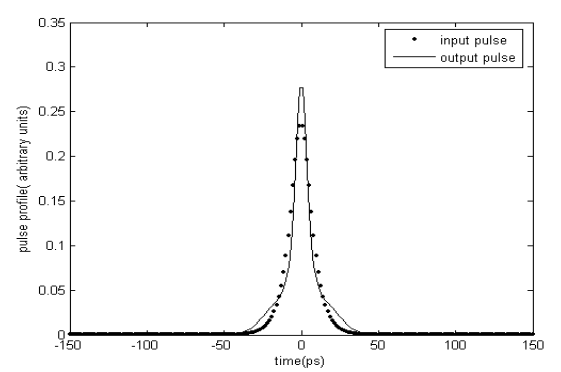
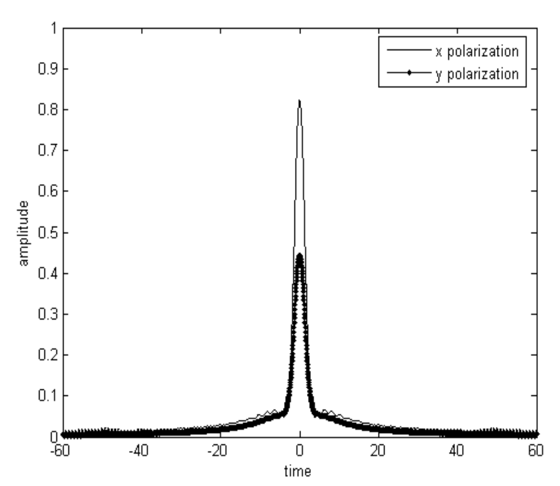


Fig.2 Pulse profile in nonlinear regime with $n_2=9/8$, $\alpha_2=2/3$ and $d_0=1$

DISPERSION:

The evolution of a pulse along the fiber is simulated by use of the split-step fast-Fourier-transform algorithm operating on Eq. (16). In this algorithm the fiber is subdivided into small sections in which the dispersion and the nonlinearity can be taken into account separately, in the frequency and the time domains respectively. The length of the Fast-Fourier-Transform vector used for our calculations is 2048. To deal with edge effects, we enlarge the computational region, by a factor of 2 or 4 to Z= (-80,80) or Z=(-160,160) . As one may expect, the relative magnitude of k_2 and k_3 depends on the deviation of the optical wavelength λ_0 from zero-dispersion wavelength λ_D, the smaller λ_0 deviates from λ_D, the larger k_3 is. For 5-psec pulse we can obtain $\Gamma = 0.0105$, which corresponds to a loss of 0.2 dB/km.The length of the fiber used for the simulations is 5 solitonperiods



CONCLUSION:

In this project we studied behavior of solitons in fibers with randomly varying birefringence and the effective pulse propagation equation in randomly varying birefringent fibers with a stochastic partial differential equation. We also reported an extensive study on the influence of PMD on soliton transmission systems. We find that the degradation mechanism of PMD on soliton systems is different from that on linear systems. In soliton transmission systems, the main problem is the PMD induced dispersive waves. This effect will degrade the soliton system performance.

Soliton propagation in birefringent single mode fiber is mainly depends on random birefringence and birefringence angle. So far coupled nonlinear Schrödinger equation is not studied with the random birefringence angle $\theta(z)$. In this project we analyze the coupled nonlinear Schrödinger equation with $\theta(z)$ term and effect of third order dispersion on soliton propagation.

We have examined the behavior of optical pulses in birefringent single mode optical fiber near the zero-dispersion wavelength. When the pulses propagate at the zero-dispersion wavelength the third-order dispersion plays a crucial role and its effects must be carefully investigated. We have shown that effects of the third-order dispersion on the soliton propagation. The third-order dispersion has different effects on the two polarizations. The solitons produced and their subsequent evolutions depend on energy of the launched pulse and the fiber parameters. It is found that the third-order dispersion in the fibers is strong enough to cause the pulse distortion.

The existing analysis of solitons does not contain the soliton propagation including both random birefringence and third order dispersion. In this project we study the propagation of soliton in a birefringent and third order dispersion in the existing CNLSE fiber by including both random birefringence effect.

BIBLIOGRAPHY:

- C. R. Menyuk, “Nonlinear pulse propagation in birefringent optical fibers,” IEEE J. Quantum Electron., vol. QE-23, pp. 174–176, 1987.
- D. Marcuse, C. R. Menyuk, and P. K. Wai, “Application of the Manakov- PMD equation to studies of signal propagation in optical fibers with randomly varying birefringence,” J. Ligh wave Techno. vol. 15, pp. 1735–1746, Sept. 1997
- I. Nishioka, T. Hirooka, and A. Hasegawa, “Effect of map strength on polarization mode dispersion in dispersion-managed soliton systems,” IEEE Photon. Technol. Lett., vol. 12, pp. 1480–1482, Nov. 2000.